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Optimization of thin-bed analysis using Image and Sonic logs in Unconventional Reservoirs - Advanced Geo-mechanical Case Application

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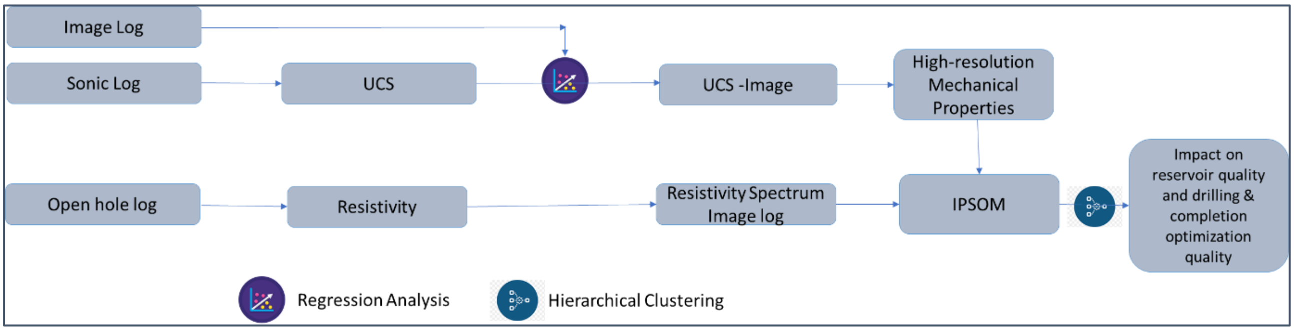
Introduction

Advances in integrated, high-resolution reservoir characterization can be applied to enhance efficiencies in the further development of unconventional reservoirs. The optimized production of unconventional reservoirs is dependent on lateral wellbore placement and completion practices. A high-resolution, integrated, electro-facies model can be utilized to provide a more representative characterization of the reservoir properties and aid in both critical components. Dipole sonic-derived mechanical property outputs do not adequately resolve thin beds and therefore do not provide a representative characterization of the reservoir for stimulation modelling and subsequent completion optimization. A novel workflow is proposed to address this challenge, with the integration of high-resolution borehole image data & geo-mechanical logs using SOM (Self organizing Map) data analytics model, as applied to the Eagle Ford shale unconventional reservoir.

Workflow

This workflow consists of three components. Firstly, the geomechanical results from acoustic data are compared with the available image data. Secondly, fine-tuning of the conventional geo-mechanical outputs is performed, using the high-resolution borehole image data. And it has been calibrated with resistivity spectrum analysis results. The borehole image fine-tuned mechanical property (in this case UCS - Unconfined Compressive Strength) is output and compared with the original, dipole sonic-derived UCS data. Finally, the high-resolution UCS is incorporated in the SOM (self-organizing map) based model to achieve a more representative geomechanical electro-facies model.



Results

The image calibrated high-resolution UCS data from this calculation with the original result and with the image data as well, the following observations were made.

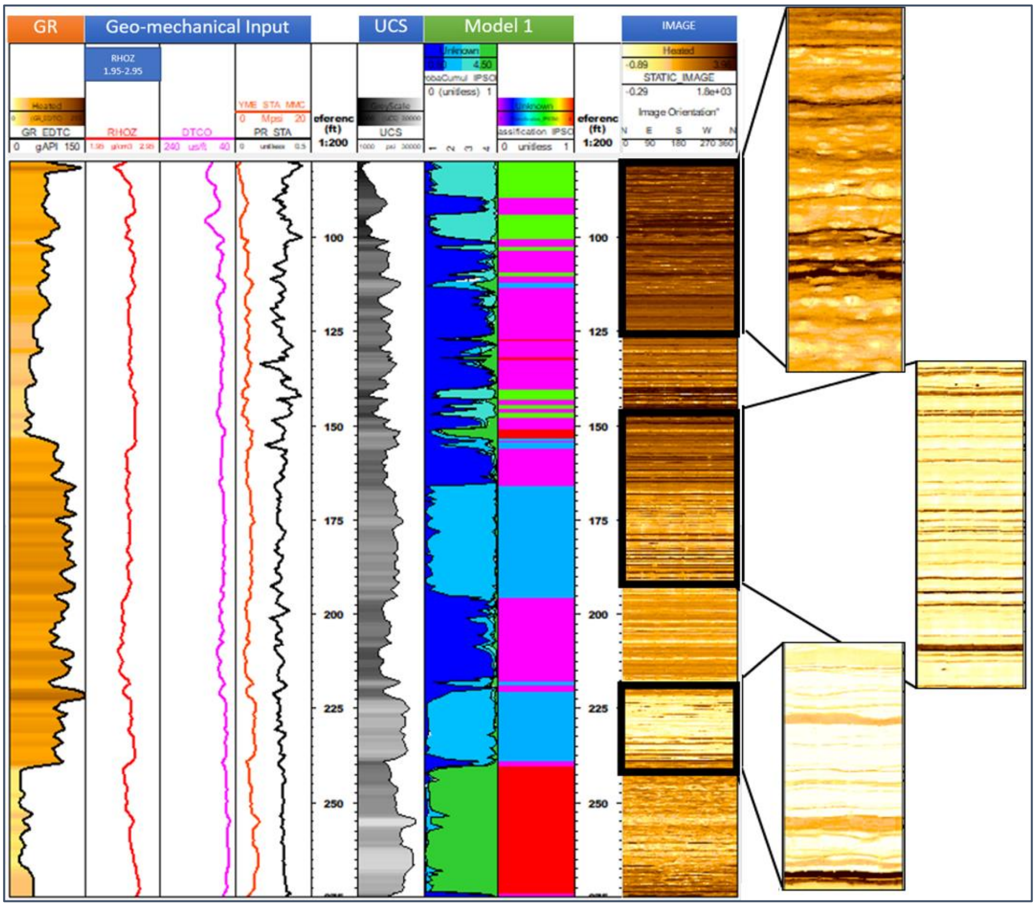


Figure 1 *Conventional logs (i.e. GR, PR, YME, UCS) falls short to represent the variations of features and lamination, shown in image log*

- Eagle-ford shale comprises of highly laminated thin beds, as clear from the resistivity image data. An overlying horizon of layered nodules are not resolved from conventional logs and geo-mechanical outputs. The SOM model (Model 1 in figure 1), based on conventional resolution petrophysical and acoustic logs, does not accurately represent the reservoir properties.

- High-resolution mechanical image (right-most track figure 2) and high-resolution UCS (UCS_IMGCAL) data was able to differentiate the intricate alternation of competent-incompetent shale laminations. And in the nodular zones, the UCS-calibrated image is properly showing the competent nodules.
- Image-based high resolution UCS data helped in achieving a high-resolution geo-mechanical SOM based electro-facies model (Model 2) where high-resolution UCS reduced the uncertainty of the unconventional thin-laminated shale reservoirs are rich in kerogen. The resolution difference of Model 1(with conventional UCS) and Model 2(with image calibrated UCS) shows that the second has better capability to resolve the intricate changes in the reservoir.

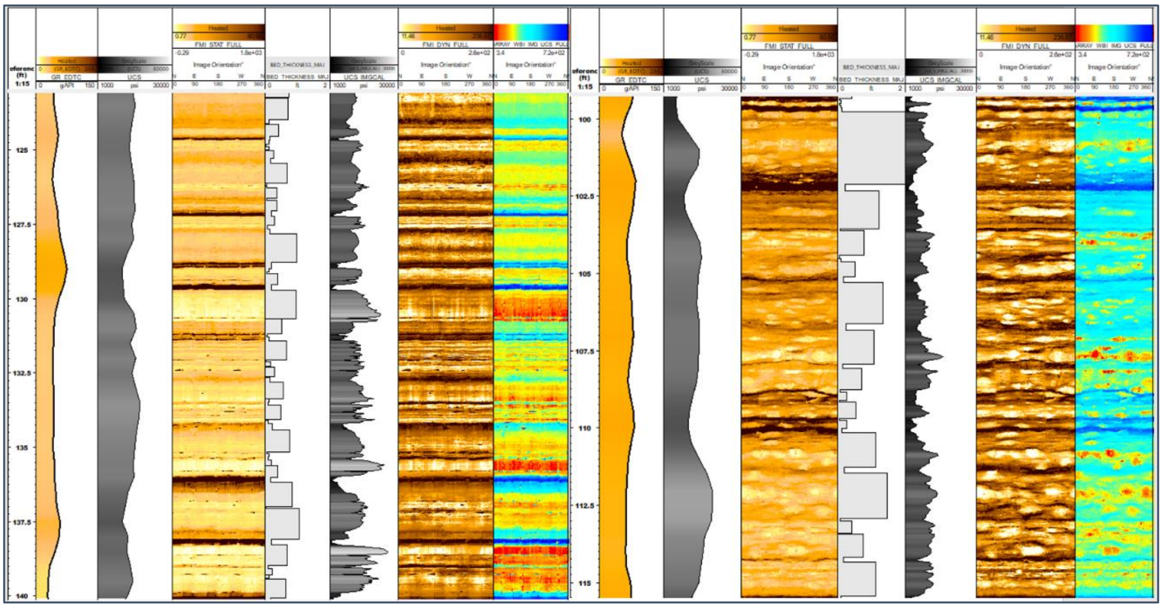


Figure 2 *High resolution mechanical image (right-most track) and high-resolution image derived UCS(UCS_IMGCAL) showing minute variations in laminations (in the left image) and intrinsic layer properties like concretions/nodules (in the right image)*

Conclusions

The high-resolution mechanical image, derived using resistivity image and mechanical log, is critical in the nodular/deformed zones to understand the intrinsic mechanical heterogeneity of the formation which does not reflect in conventional logs. This analysis with high-resolution synthetic mechanical-image and UCS output from image gives the ability to reduce the uncertainty in relatively low resolution geo-mechanical data from acoustic tools, leading to better SOM based electro-facies estimation (figure 3). Core-like SOM facies with optimized UCS and Resistivity spectrum analysis (binned-array outputs) are a unique solution in terms of geo-mechanical aspect of Shale oil/gas reservoirs like this. In bigger aspect it can

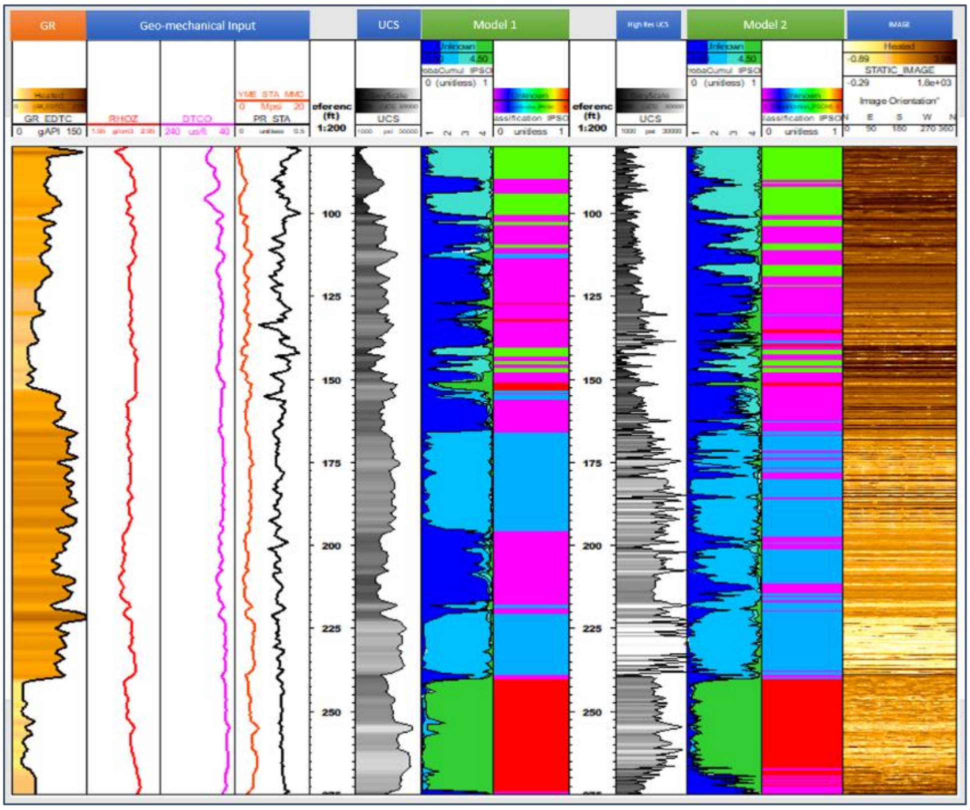


Figure 3 *High resolution image derived UCS combining with conventional logs produces better SOM model*

prove beneficial in terms of reservoir-based analysis across multiple wells as well. Efficacy of characterization and geomechanical model owing to this workflow would help in further field development studies of Eagle Ford formation in USA.

Refences

Geology of Eagle-Ford shale: https://eaglefordshale.com/geology